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NIOSH

Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *November 22, 2006*

Fire Fighter/Emergency Medical Technician Suffers an Acute Myocardial Infarction and Dies Three Days Later – Pennsylvania

SUMMARY

On November 21, 2005, a 41-year-old male career Fire Fighter/Emergency Medical Technician (FF/EMT) worked his 24-hour shift, during which he participated in a live-fire exercise and responded to a sprinkler system low-air alarm. The next morning, November 22nd, the FF/EMT went home after his shift and painted a bathroom. He experienced chest pain and called 911. Shortly after the ambulance arrived, he suffered a cardiac arrest and was transported to a hospital where he was treated and then transferred to another hospital for advanced cardiac care. Testing revealed he had suffered an acute heart attack (myocardial infarction [MI]). His condition deteriorated, and he died three days later. The death certificate (completed by the attending physician) listed "atherosclerotic heart disease" due to "acute myocardial infarction" as the cause of death. The autopsy (performed by the pathologist) listed "arteriosclerotic cardiovascular disease (CVD) with acute myocardial infarction; pulmonary emboli" as the cause of death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unlikely any of these recommendations would have prevented this FF/EMT's death.

Incorporate exercise stress tests (ESTs) for fire fighters at increased risk of coronary artery disease (CAD) into the fire department's (FD) periodic medical evaluation program.

Discontinue routine annual electrocardiograms (EKGs) unless medically indicated.

Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural firefighting.

INTRODUCTION & METHODS

On November 21, 2005, a 41-year-old male FF/EMT participated in live-fire training and responded to a low-air alarm during his 24-hour shift. On November 22nd, the FF/EMT suffered an acute heart attack and died three days later. On January 12, 2006, NIOSH contacted the affected FD to obtain further information, and on April 17, 2006 to initiate the investigation. On May 8, 2006, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Pennsylvania to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- The District Fire Chief
- The Union local President
- Crew members
- The FF/EMT's wife

During the site visit, NIOSH personnel reviewed the following documents:

- FD policies and operating guidelines
- FD training records
- The FD annual report for 2005

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- Witness statements
- FD dispatch records
- FD physical examination protocols
- Ambulance response report
- Hospital records
- Occupational medical records
- Primary care physician (PCP) medical records
- Death certificate
- Autopsy record

INVESTIGATIVE RESULTS

Incident. On November 21, 2005, the FF/EMT reported for work at 0730 hours. The FF/EMT was assigned to be the driver/operator of Engine 1. The morning was spent performing roll call, apparatus and equipment checks, and station cleaning. At 0930 hours, the crew began the day's training program with municipal water supply (fire hydrants and water flow measurements) and live-fire training utilizing a burn trailer (see Photograph). Crew members drove the apparatus to the training site, walked through the burn trailer, and received instruction on the training to be conducted. A 3-inch supply line was stretched from the hydrant to the Engine. A 1¾-inch handline was stretched from the Engine to the burn trailer. Five training evolutions were conducted utilizing two, two-person teams. Each team performed two evolutions so that each person could function as the nozzle-operator. Each fire fighter wore full turnout gear and self-contained breathing apparatus (SCBA) on-air. The team entered the burning structure and completed fire extinguishment, taking approximately two minutes. The FF/EMT performed as the driver/operator for the first four evolutions. He performed as the nozzle-operator along with a partner to complete the fifth evolution. Training continued until about 1200 hours; hoses were taken up and reloaded onto the apparatus, and the crew returned to their fire station. The crew then refilled their SCBA bottles and ate lunch.

At 1300 hours, the crew conducted classroom training on firefighting and ventilation practices. The FD received a sprinkler system low-air alarm at 1320 hours; E-1 (a crew of four members including the FF/EMT), Utility 1 (a crew of two members), and the Battalion Chief responded. Arriving at the scene within one minute, the crew learned that contractors had accidentally activated the fire alarm. The FF/EMT (serving as driver/operator) stayed with Engine 1 as the E-1 crew checked the building. Finding nothing, they reset the alarm panel and returned to the fire station.

The crew conducted no further operations during their shift. The FF/EMT did not report any symptoms or any medical problems, but, upon their return to the fire station, he retired to his quarters to rest. The FF/EMT spoke to his wife about 2115 hours. He mentioned that the training was very difficult and that he did not feel well. The next morning, November 22nd, the crew awoke at approximately 0700 hours. The FF/EMT mentioned to a crew member that he felt badly, but gave no specific details. The crew parted company at 0800 hours (at shift change) and each fire fighter left the fire station. The FF/EMT drove approximately 40 minutes to his home.

After the FF/EMT arrived at his home, he spent the morning painting

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a bathroom, finishing at about 1300 hours. He spoke to his wife shortly thereafter, but he did not complain of any cardiac-related problems. At about 1415 hours, the FF/EMT phoned 911 with complaints of crushing chest pain.

An ambulance was dispatched at 1416 hours and arrived at his home at 1418 hours. The FF/EMT opened the front door for the ambulance EMTs and then sat on a sofa. He complained of substernal crushing chest pain. His vital signs were obtained and oxygen was administered via non-rebreather mask. Suddenly, the FF/EMT stopped breathing and became unresponsive and pulseless. The EMTs lifted him over the sofa and placed him onto a stretcher. Cardiopulmonary resuscitation (CPR) (chest compressions and oxygen delivery via bag-valve-mask) was begun and an oral airway was placed. An automated external defibrillator (AED) was attached to the FF/EMT and a shockable heart rhythm (ventricular fibrillation) was detected, for which two shocks were delivered. The FF/EMT was placed into the ambulance, which departed for the hospital at 1430 hours. CPR continued en route to the hospital. The AED identified a shockable heart rhythm (ventricular fibrillation), and a third shock was delivered with no change in the FF/EMTs heart rhythm. The ambulance arrived at the hospital's emergency department (ED) at 1432 hours.

Inside the ED, the FF/EMT was found to be unresponsive, pulseless, and cyanotic with CPR in progress. Advanced life support (ALS) measures were initiated, including intravenous (IV) access, intubation, cardiac resuscitation medications, and cardiac monitoring. Two additional shocks were delivered and a pulse returned at 105 beats per minute (bpm). An EKG revealed an anterior wall infarction (heart attack).

The FF/EMT was transferred to another hospital for advanced cardiac care. EKGs revealed heart rates ranging from 104 bpm to 117 bpm with arrhythmias (right bundle branch block and premature ventricular beats) and signs of acute heart damage in the septal, lateral, and anterolateral regions. He was placed on a breathing machine (ventilator). Early the next morning, November 23rd, the FF/EMT suffered another cardiac arrest and was successfully resuscitated. Cardiac catheterization revealed a totally occluded left anterior descending artery. The FF/EMT was in cardiogenic shock and an intraaortic balloon pump was placed to maintain his blood pressure/circulation. An echocardiogram revealed an ejection fraction of <10%, ischemic cardiomyopathy, and mild mitral valve regurgitation. A normal left ventricular ejection fraction (LVEF) is generally considered >50%.[1] Neurological examination indicated the FF/EMT experienced severe brain damage due to lack of oxygen (hypoxic encephalopathy). The FF/EMT died at 1225 hours on November 25, 2005.

Medical Findings. The death certificate (completed by the attending physician) listed "atherosclerotic heart disease" due to "acute myocardial infarction" as the cause of death. The autopsy (performed by the pathologist) listed "arteriosclerotic cardiovascular disease with acute myocardial infarction; pulmonary emboli" as the cause of death. Pertinent findings from the autopsy, performed on November 27, 2005, included the following:

- Arteriosclerotic CVD
  - Occluded (100%) left anterior descending coronary artery
- Extensive left ventricular MI
- Cardiomegaly (enlarged heart: heart weighed 550 grams [g] [normal is <400 g])[2]
- Biventricular hypertrophy
  - Left Ventricular Hypertrophy (LVH) (wall thickness was 2.0 centimeters [cm] [normal is 0.6 cm - 1.1 cm])[3]
  - Right Ventricular Hypertrophy (RVH) (wall thickness was 0.9 centimeters [cm] [normal is 0.3 cm - 0.5 cm])[4]
- Microscopic examination revealed an "early thrombus at the site of the ventricular infarction"

- Microscopic evidence of thromboemboli in the pulmonary arteries with pulmonary infarction

Medical records indicated the FF/EMT had been diagnosed with hypercholesterolemia in 1996. He was prescribed one cholesterol-lowering medication in 2000 and another in 2001. However, the medication was not identified on his FD medical evaluations. At his 2003 FD medical evaluation, the physician recommended the FF/EMT see his PCP for elevated cholesterol (233 milligrams per deciliter [mg/dL]) (normal is 100 – 200 mg/dL) and low-density lipoprotein (156 mg/dL) (normal is 0 – 130 mg/dL) levels.

The FF/EMT was hospitalized for chest pain/rule out MI in 1998 and 2000. Both episodes ruled out for an MI. His discharge diagnosis in 1998 was "palpitations" and he was advised to avoid caffeine, nicotine, chocolate, and pseudoephedrine. In 2000, a stress echocardiogram was performed during which the FF/EMT exercised for nine minutes on the Bruce protocol. He showed no signs of ischemia by EKG or clinical echocardiogram criteria. He was discharged and prescribed medication for smoking cessation. The FF/EMT had not expressed any signs or symptoms of chest pain to his wife or co-workers prior to this incident, only that he felt badly.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the FD consisted of 16 uniformed career personnel and served a Facility population of 3,000. There is one fire station. Fire fighters work shifts from 0800-0800 hours, and work 24 hours on-duty, 24 hours off-duty for six tours of duty, then are off-duty for three days.

In 2005, the FD responded to 394 calls: 12 fires, 99 alarm/false alarm/false calls, 72 flooding/water evacuation/leak/other problem calls, 62 medical/rescue/extrication calls, 61 potential accidents, 21 sprinkler activations, 21 detector/activations, 19 hazardous material/condition calls, 11 good intent/service calls, 11 standby/assist/cover assignment calls, and 5 other calls.

Employment and Training. The FD requires all new fire fighters to pass a pre-placement physical examination and a physical agility test. The new fire fighter must be pre-certified to the level required by the vacant position (minimum of Fire Fighter I and II). All personnel are required to pass emergency vehicle operator course (EVOC) training prior to operating FD vehicles. Subsequent training is conducted on-shift. Fire fighters certified in hazardous materials (Hazmat), CPR, and EMT are re-certified annually. The FF/EMT was certified as a Fire Fighter II, Fire Officer I, EMT, Driver/Operator, Hazmat Operations, Fire Inspector I, Telecommunicator I, and had 11 years of firefighting experience.

Pre-placement Medical Evaluations. The FD requires a pre-placement medical evaluation for all new hires, regardless of age. Components of this evaluation include the following:

- History
- Vital signs
- Physical examination
- Blood tests: Complete Blood Count, Metabolic Profile, Lipid Profile, and Liver Function
- Urinalysis
- Pulmonary Function Test
- Resting EKG
- Chest x-ray
- Audiometry
- Vision test

These evaluations are performed by the Facility physician, who makes a determination regarding medical clearance for firefighting duties and forwards this decision to the FD.

Periodic Medical Evaluations. Periodic medical evaluations are required annually by this FD. Components of these evaluations are the same as those of the pre-

placement evaluation, with the exception of chest x-rays, which are conducted as required by the examining physician. These evaluations are performed by the Facility physician, and the medical clearance decision for each examination is forwarded to the FD. If a medical evaluation reveals an abnormality, the Facility physician will refer the fire fighter to their PCP for further testing. The results of this testing are then reviewed by the Facility physician, and the medical clearance decision is forwarded to the FD. If an employee is injured at work, or becomes ill and misses more than three shifts, the employee is evaluated and must be cleared for return to work by the Facility physician. Input from the employee's PCP is also considered at this point. According to medical records obtained by the NIOSH investigator, the FF/EMT's last FD medical evaluation was in March 2005. He was never restricted from duty for CAD symptoms.

Fitness/Wellness Programs. The fire station has exercise (strength and/or aerobic) equipment. Participation in fitness training is mandatory and time is allotted for exercise. Wellness programs (smoking cessation, weight control, high blood pressure [BP], diabetes, and cholesterol) are also offered by the Facility.

DISCUSSION

CAD and the Pathophysiology of Sudden Cardiac Death. In the United States, CAD (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[5] Risk factors for its development include increasing age, male gender, family history, tobacco smoking, diabetes, high blood cholesterol, high BP, and physical inactivity/obesity.[5] The FF/EMT had four risk factors for CAD as defined by the American Heart Association: male gender, family history, tobacco smoking, and high blood cholesterol.[5] Not only did the FF/EMT have risk factors for CAD, but, on autopsy, he had CAD (a totally occluded left anterior descending coronary artery).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[6] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[7] Heart attacks (MIs) typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply.[8] The FF/EMT had an MI as determined by EKG and autopsy findings.

This sudden blockage is primarily due to blood clots (thromboses) forming on the top of atherosclerotic plaques. The FF/EMT was found to have microscopic thrombus formation on autopsy. The formation of blood clots (thromboses) in coronary arteries is initiated by disruption of atherosclerotic plaques. Certain characteristics of the plaques (size, composition of the cap and core, presence of a local inflammatory process) predispose the plaque to disruption.[8] Disruption then occurs from biomechanical and hemodynamic forces, such as increased BP, increased heart rate, increased catecholamines, and shear forces, which occur during heavy exercise.[9]

Firefighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[10] Firefighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 bpm), owing to the insulative properties of the personal protective clothing.[11] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[12-15] The FF/EMT participated in fire suppression training (about 26 hours prior to his first recognized symptom [chest pain]) while wearing bunker gear and SCBA. This is considered a heavy level of physical exertion.[10,16] The physical stress of performing fire suppression training and the presence of underlying atherosclerotic CVD may have contributed to this fire fighter's heart attack and subsequent cardiac arrest.

The FF/EMT also had biventricular (left and right ventricular) hypertrophy and cardiomegaly on autopsy. Hypertrophy of the heart's left ventricle (LVH) is a relatively common finding among individuals

with long-standing high BP (hypertension), a heart valve problem, or cardiac ischemia (reduced blood supply to the heart muscle).[2] The FF/EMT was never known to have high BP or heart valve problems on his echocardiogram in 2000. Therefore, his biventricular hypertrophy was most likely due to cardiac ischemia. LVH increases the risk for sudden cardiac death.

The FF/EMT did not, however, report symptoms of angina (e.g., chest pain on exertion) to family or crew members in the days or weeks prior to his collapse, nor to his physicians during the months/years prior to his death. Unfortunately, up to 20% of MIs are asymptomatic (i.e., no angina).[17] His most recent episode of chest pain had occurred in 2000 and work up at that time (a stress echocardiogram for nine minutes on the Bruce protocol) was negative.

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments*.[18] NFPA 1582 recommends (for informational purposes only) that fire fighters over the age of 45 (for men) and 55 (for women) with two or more risk factors for CAD be screened for obstructive CAD by an EST. NFPA defines these CAD risk factors as: hypercholesterolemia (total blood cholesterol level >240 mg/deciliter [dL]), hypertension (systolic BP greater than 140 millimeters of mercury [mmHg] and/or diastolic BP >90 mmHg), smoking, diabetes mellitus, or family history of premature CAD (first-degree relative <age 60).[18] This guidance is similar to recommendations from the ACC/AHA (see below) and the U.S. Department of Transportation (DOT) regarding ESTs in asymptomatic individuals.[19,20] Since the FF/EMT had two NFPA risk factors for CAD (family history and tobacco smoking) but was less than age 45, an EST would not have been recommended by NFPA 1582.[18] However, the FF/EMT had a submaximal stress echocardiogram in 2000 due to symptoms of chest pain. NFPA 1582 recommends maximal stress electrocardiography together with imaging techniques for diagnostic purposes for FFs with new onset of chest pain or other symptoms suggestive of CAD. [18]

Conducting ESTs on asymptomatic individuals is controversial. The ACC/AHA states that the evidence for conducting ESTs on asymptomatic individuals is "less well established" (Class IIb) for the following groups:

1. People with multiple risk factors (as a guide to risk-reduction therapy, with the risk factors being essentially the same as those of the NFPA listed above)

2. Asymptomatic men older than 45 years, and women older than 55 years:
   - Who are sedentary and plan to start vigorous exercise
   - Who are involved in occupations in which impairment might jeopardize public safety [e.g., fire fighters]
   - Who are at high risk for CAD due to other diseases (e.g., peripheral vascular disease and chronic renal failure).[19]

The U.S. DOT also addresses the issue. To obtain medical certification for a commercial driver's license, DOT recommends an EST for drivers over the age of 45 who have more than two risk factors for CAD.[20] Finally, the U.S. Preventive Services Task Force (USPSTF) does not recommend ESTs for asymptomatic individuals, even those who have risk factors for CAD. Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes).[21] The USPSTF indicates there is insufficient evidence to recommend screening middle age and older men or women in the general population, but notes that "screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety."

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unlikely any of these recommendations would have prevented this FF/EMT's death.

Recommendation #1: Incorporate ESTs for fire fighters at increased risk of CAD into the FD's periodic medical evaluation program.

NFPA 1582 recommends ESTs for fire fighters over the age of 45 (for men) and 55 (for women) with two or more risk factors,[18] and the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) *Wellness/Fitness Initiative* recommends an EST at any age.[22] The AHA states an EST may be indicated for individuals who have two or more risk factors for CAD, and are over 45 years of age.[19] The EST could be conducted by the fire fighter's PCP (at FD expense) or the Facility physician. If the fire fighter's PCP conducts the test, the results must be communicated to the Facility physician, who should be responsible for decisions regarding medical clearance for firefighting duties.

Recommendation #2: Discontinue routine annual EKGs unless medically indicated.

According to NFPA 1582, "periodic resting electrocardiograms have not been shown to be useful, but can be reasonable as a member's age increases."[18] The stress EKG is a much better tool to identify heart abnormalities. Therefore, only pre-placement EKGs are recommended unless medically indicated by other information. The EKGs being conducted by the FD represent an unnecessary expense for the Facility and should only be performed as medically necessary.

Recommendation #3: Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural firefighting.

NFPA 1500 requires FD members who engage in emergency operations to be annually evaluated and certified by the FD as meeting the physical performance requirements identified in paragraph 8-2.1.[23] The FD should conduct annual physical ability tests to ensure the fire fighters are physically capable of performing firefighting duties.

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